

# ***Designing Integrated Solutions to Complex Problems***



## **Systems Engineering Education at West Point**

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Acting SE Program Director  
7 April 2010**



# Topics



- Context
  - The West Point Program
  - The Department of Systems Engineering
- The Systems Engineering Curriculum
  - Objectives
  - Design
- Thoughts on Undergraduate SE Teaching





# West Point Academic Program



**Army Officer**

**Bachelor of Science Degree**

**10 to 14 Courses for Major**

**4 Military Science**

**4 Physical Education**

1 Philosophy/Ethics  
2 Foreign Language  
3 Social Sciences  
2 Leadership  
3 English  
4 History  
1 Law

16 Sem Crs  
Humanities and Social Science

**The  
Core**

3 Engineering  
2 Information Technology  
1 Terrain Analysis  
2 Chemistry  
2 Physics  
4 Math

14 Sem Crs  
Math, Science, & Engineering



# The Department of Systems Engineering



- Established 1989
- Four main programs
  - Systems Engineering major
    - 14 courses, ABET accredited
  - Engineering Management major
    - 14 courses, ABET accredited
  - Systems Management major
    - 10 courses
  - Systems Engineering sequence
    - 3 upper-division courses for non-engineers
- Operations Research Center
  - Consulting for Army clients





# Topics



## ✓ Context

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# Curriculum

## ABET Accredited - 43.3 Courses



	09-2	10-1	10-2	12-1	12-2
1	SE301	SE375	SE370	SE402	SE403
2	MA206	SE387	SE388	EM411	EM420
3	LX2XX	Sub-Discipline Elective	Simulation Elective	Sub-Discipline Elective	Sub-Discipline Elective
4	PH202	CE300	ME311	EE301	LW403
5	EV203 / PY201	SS307	SE385	HI301	HI302
6	SS20X	EN302	PL300		SE400

### Introductory Course

SE301: Foundations of Eng Design and Sys Mgmt

### Sub-Disciplines

Human Factors  
Systems  
Information Systems  
Mathematical Systems  
Simulation Systems

SE370: Computer Aided Systems Engineering  
SE375: Statistics for Engineers  
SE385: Decision Analysis  
SE387: Deterministic Models  
SE388: Stochastic Models  
EM411: Project Management  
EM420: Production Operations Management  
SE400: Professional Engineering (hr)

### General Engineering Fundamentals

CE300: Fund of Eng Mechanics and Design  
ME311: Thermal-Fluid Systems I  
EE301: Fund of Electrical Engineering

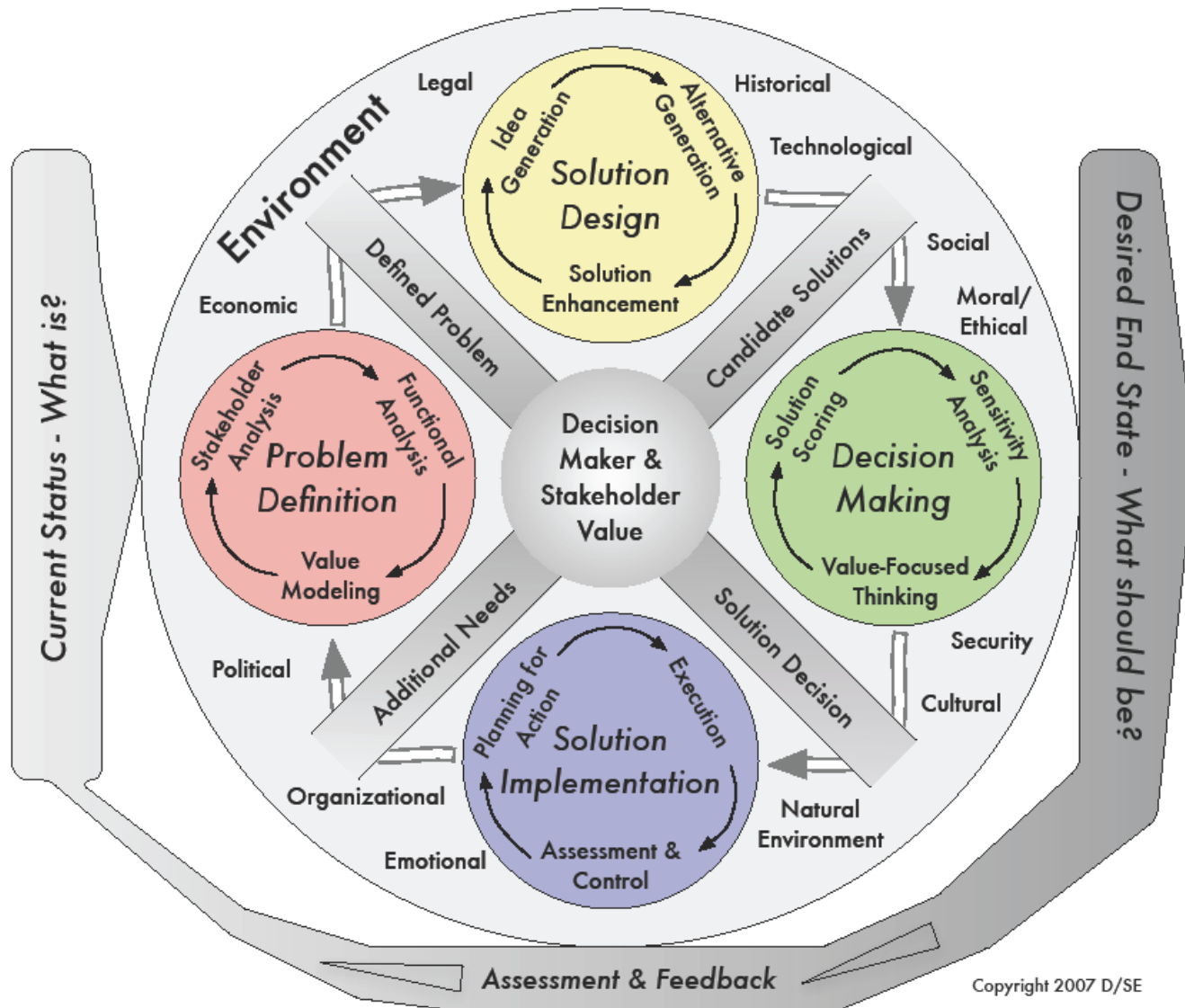
### Simulation Electives

SE481: Systems Simulation  
SE485: Combat Modeling  
EM484: Dynamic Systems Analysis

### Capstone Research

SE402/3: Systems Design I / II

# The Systems Decision Process





# Primary Peer Group Comparison USMA SE Program (AY 2010)



## **Sub-Disciplines (3 courses)**

Biomedical Systems  
Communication Systems  
**Computer and Information Systems**  
Control Systems  
Economic Systems  
Energy and **Environmental** Systems  
**Financial Systems**  
**Human Factors**  
Transportation Systems  
Management Systems  
**Mathematical Systems**  
**Student-Designed**

**Total Cr Hrs:**  
**128**

**Prog Cr Hrs:**  
**58**  
**Engineering Rigor**  
Freshman Engr (4 cr)  
**Math Rigor**  
6 courses (Lin Alg)

**Total Cr Hrs:** **141**  
**Prog Cr Hrs:** **54**

## **Engineering Rigor**

Fundamentals of Engr Mechanics  
Intro to Electrical Engineering  
Thermal-Fluid Systems I

**Math Rigor**  
5 courses



## **Common to All**

Intro Course  
Simulation  
Computer Aided SE  
Statistics  
Project Management  
Deterministic Modeling  
Stochastic Modeling  
Senior Seminar  
Two Semester Capstone

## **Common to non-USMA**

Human Factors (All)  
UML (UVA, UA)  
MATLAB (UA, GMU)  
Control Systems (UA, GMU)

## **Sub-Disciplines (3 courses)**

Human Factors Systems  
Information Systems  
Mathematical Systems  
Simulation Systems

## **Sub-Disciplines (3 courses)**

**Software**  
**Telecommunications**  
**Environmental and Infrastructure**  
**Systems Modeling and Performance**

## **Engineering Rigor**

Freshman Engr (2 cr)

**Math Rigor**

7 courses (Lin Alg, Diff Eqs)

## **Sub-Disciplines (4 courses)**

**Software Systems**  
Engineering Management  
Decision and Control  
**Information Technology**  
**Engineering Rigor**  
Freshman Engr (3 cr)  
**Elements of Electrical Engineering**  
**Math Rigor**  
5+ courses (Diff Eqs)



THE UNIVERSITY OF ARIZONA.

**Total Cr Hrs:** **128**  
**Prog Cr Hrs:** **62**

**Total Cr Hrs:** **120**  
**Prog Cr Hrs:** **61**



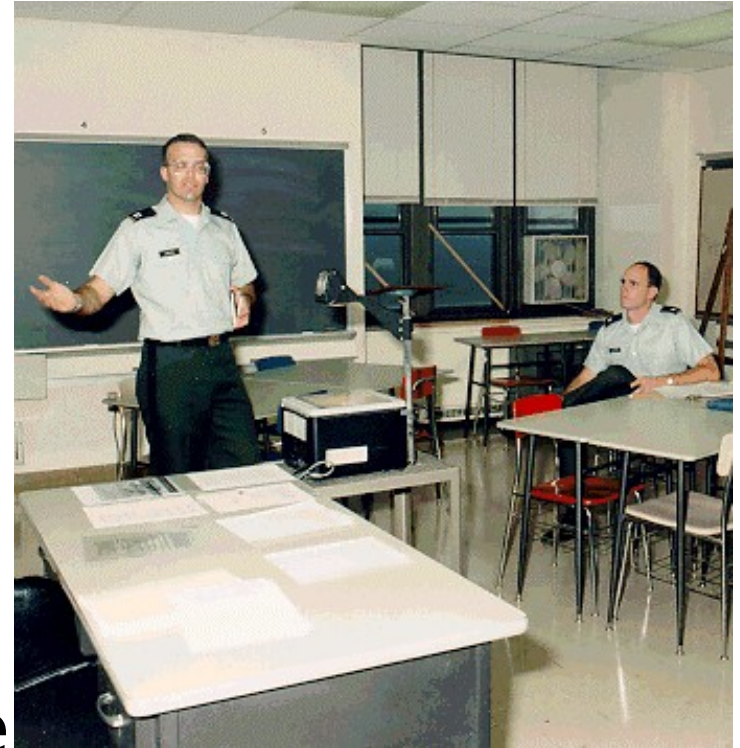




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# West Point SE Program Strengths



- Where the program is strong
  - SDP as unifying concept
  - Capstone research on real Army problems
  - Institutional cohesiveness
- Where I wish it were stronger
  - More interdisciplinary projects
  - More comfort with abstract models
  - Better teaching of use of SE computer tools
  - More “design” vice “pick from alternatives”
  - Giving a better sense of what it is like to work as a systems engineer



# Question #1 on Undergrad SE



- What do people with the job title “Systems Engineer” actually do?
  - Technical program management
  - Requirements management
  - Technical coordination
  - Architecture definition
  - Provide technical advice to management



# Question #2 on Undergrad SE



- What do we want a graduate to be able to do immediately after graduation?
  - Work as a junior engineer in the Systems Engineering shop of a large system development
  - Make good decisions in a complex technical environment
  - Start graduate work in systems engineering



# Question #3 on Undergrad SE



- What's the core of SE?
  - Modeling and analysis
  - Control systems
  - Requirements management
  - Large-scale system integration and test
  - The “ilities”
  - Decision making in a complex technical environment
  - Understanding different types of engineers and users, and translating between them





# Core Dilemmas of Undergrad SE Education



- Need for SE is only evident in large, complex engineering projects
  - At the undergraduate level it is difficult to get to such projects
- SE requires abstract thinking
  - Undergrad engineers (especially West Point cadets) tend to be concrete thinkers
- SE is inherently interdisciplinary
  - Universities are organized by discipline



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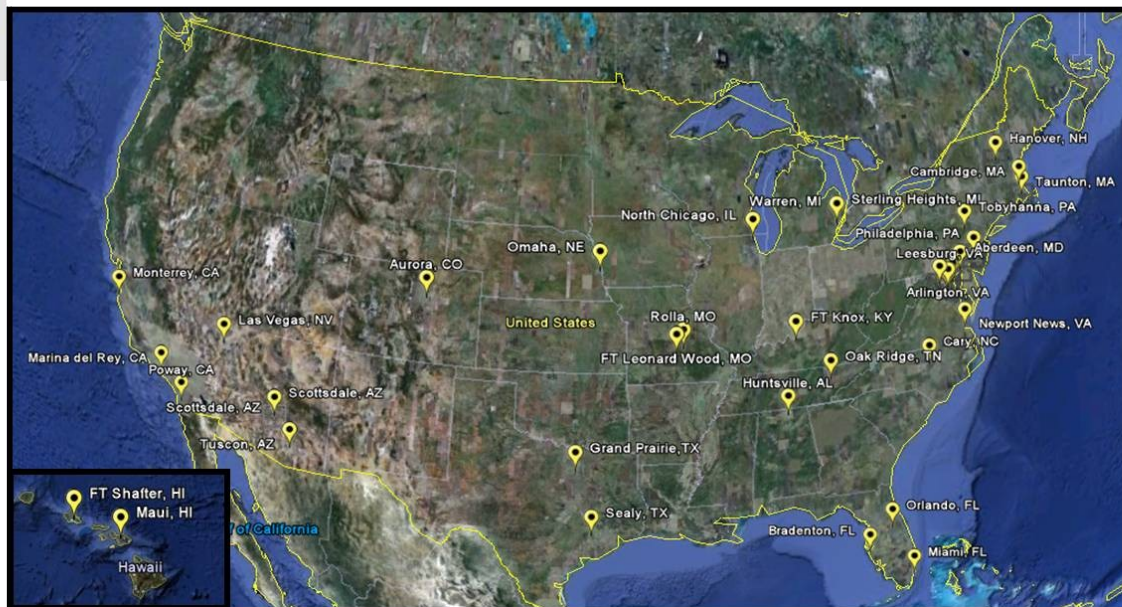


# Backups





# 2010 AIAD Footprint



Battelle

Raytheon



GENERAL DYNAMICS





# SE Sub-Discipline Offerings



## Human Factors Systems

Take the following:

PL386 Experimental Psychology  
and  
PL485 Human Factors Engineering

and either:\*

PL490 Engineering Psychology Design  
or  
PL488E Human Error

## Mathematical Systems

Take the following:

EM381 Engineering Economy  
and two of the following:\*  
MA366 Vector Calculus and Intro to PDE  
MA371 Linear Algebra  
MA381 Nonlinear Optimization  
MA386 Introduction to Numerical Analysis  
MA391 Mathematical Modeling  
MA476 Mathematical Statistics  
MA481 Linear Optimization  
MA488 Special Topics in Mathematics  
MA490 Applied Probability from Math, Science and Engineering

## Information Systems

Take the following:

CS301 - Fundamentals of Computer Science  
and  
SE482 Command and Control Systems  
and one of the following:\*  
CS350 Database Design and Implementation  
IT382 Networked Systems Management  
IT383 Human Information Interfacing  
IT460 Information Warfare  
CS482 Information Assurance  
EV398 Geographic Information Systems

## Simulation Systems

Take the following:

Take one (or two) of the remaining two simulation electives offered in the Department of Systems Engineering  
and two (or one) of the following:\*  
MS365 Campaigning: Operational Warfighting  
MA476 Mathematical Statistics  
EV398 Geographical Information Systems  
The other simulation elective offered in DSE

**\*SE489 Advance Topics in Systems Engineering and Engineering Management or XE495 Topics: Advanced Technology can be taken in lieu of one of these courses by approval of the SE Program Director**

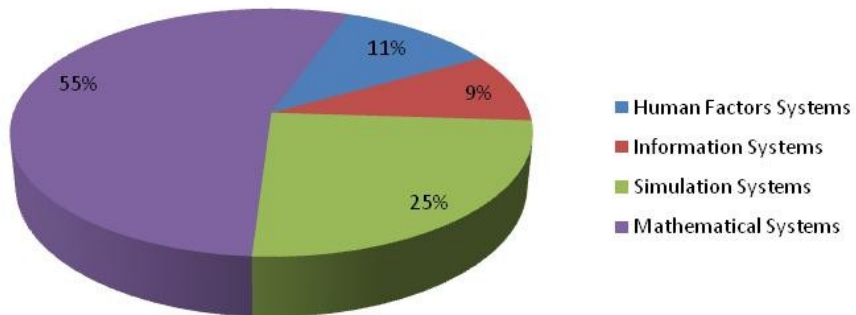




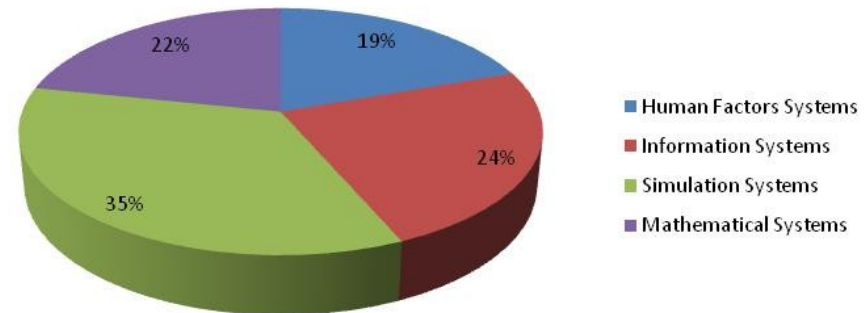
# Sub-Discipline Enrollments

CLASS	Human Factors Systems	Information Systems	Simulation Systems	Mathematical Systems	TOTALS
2010	5	4	11	24	44
2011	9	11	16	10	46
TOTALS	14	15	27	34	90

Class of 2010 SE Sub-Disciplines



Class of 2011 SE Sub-Disciplines





# SE Program Objectives



1. Produce graduates for a career of professional excellence and service to the Nation as an officer in the United States Army.
2. Produce graduates who effectively lead interdisciplinary teams in Joint, Combined, inter-agency, and multicultural environments.
3. Produce graduates who solve complex systems engineering problems in uncertain future environments.
4. Produce graduates who communicate engineering solutions convincingly both orally and in writing to technical and non-technical audiences.
5. Produce graduates who seek out and succeed in continued intellectual professional development in systems engineering and related fields.



# SE Program Outcomes



1. Define the problem, design solutions, make decisions, and implement the chosen engineering solution within a **broad global and societal context**.
2. **Act professionally and ethically** as a leader of character within each stage of the system lifecycle.
3. Lead and work effectively as a contributing member of **multidisciplinary systems engineering teams**.
4. Employ up-to-date **techniques, skills, and engineering tools** necessary for Army officers and systems engineering practice.
5. Identify and **formulate a client's engineering problem** and specify the client's actual needs using systems thinking, systems engineering and systems decision-making.
6. Apply knowledge of contemporary **stakeholder issues** to systems decision making.
7. Define and **measure system performance** to guide solution design, systems decision-making and to validate that the design solution adds value and solves the defined problem.
8. Design or re-engineer a system or process in order to **develop innovative alternatives** that meet the needs of the client within realistic environmental constraints such as cultural, historical, legal, moral/ethical, economic, environmental, organizational, emotional, social, political, and technological.
9. **Apply knowledge of mathematics, science, and engineering** appropriate to Army officers and practicing systems engineers in order to develop, quantitatively evaluate, and implement effective and efficient solutions.
10. Design and conduct systems **experiments**, including collecting, analyzing, and interpreting data.
11. Accurately, clearly, and concisely **report findings**, conclusions, and recommendations to the client in a manner that supports the client's decision.
12. Demonstrate the skills necessary to support **continued intellectual growth** and learning for a career of professional excellence and service to the nation as an officer in the United States Army.



# The Way Ahead for SE



## **a. Evolving trends in discipline of Systems Engineering**

- o Increasing involvement of professional organizations in undergraduate education
- o Increasing emphasis on interdisciplinary education

## **b. Impacts of those trends**

- o Standardization among diverse programs
- o Requirements for true cross-disciplinary system-level experiences

## **c. Potential changes to SE Program**

- o Closer relationships with the International Council on Systems Engineering (INCOSE) to influence developing standards
- o Interdisciplinary capstones (with cadets from other engineering programs)
- o More sub-discipline tracks (e.g. Space Systems, Financial Systems)



# Courses



- **SE301:** Foundations of Engineering Design & Systems Management
- **SE370:** Computer Aided Systems Engineering
- **SE375:** Statistics for Engineers
- **SE385:** Decision Analysis
- **SE387:** Deterministic Models
- **SE388:** Stochastic Models
- **SE481:** Systems Simulation
- **SE402/3:** Systems Design I/II





# SE301: Foundations of Engineering Design & Systems Management



- Introduction to System Decision Process
- Execution of SDP on non-complex problems
- Only course where Problem Definition is taught explicitly
- Revision being considered
  - Improve coverage of some topics, including functional and design analysis
  - Add more actual “design”



# SE370: Computer Aided Systems Engineering



- MS Office
  - Excel (9 Lessons)
  - Access (9 Lessons)
  - Project (3 Lessons)
  - PowerPoint (1 Lesson)
- Visio (2), SharePoint (2), CORE (2), GIS (10)
- Revision planned for AY 2010-11
  - Reduce MS Office
  - Reduce overlap with other courses
  - Increase uniquely engineering content



# SE375: Statistics for Engineers



- Builds on core curriculum course MA206
- Confidence intervals
- Non-parametric statistics
- Analysis of variance
- Design of experiments
- Linear regression
- Course project



# SE385: Decision Analysis



- Decision trees
- Influence diagrams
- Risk profiles
- Multiple attribute decision analysis



# SE387: Deterministic Models



- Linear programming
- Nonlinear programming
- Integer programming
- Networks
- Life cycle costing





# SE388: Stochastic Models



- Markov chains
- Queues



# SE481: Systems Simulation



- **Discrete event simulation**
- **Approved alternatives:**
  - **SE485: Combat Modeling**
    - **Combat simulations**
  - **EM484: Dynamic Systems Analysis**
    - **System dynamics**



# Capstone Projects *1 of 3*



Capstone Advisor	Supported Agency	Project Title
MAJ Rob Dees	U.S. Army G-1	What is a Quality Officer?
MAJ Rob Dees	USMA	Cadet Quality
LTC Kelly Ward	U.S. Army Geospatial Center	Representing Unmanned Helicopter Resupply Points as Tactical Spatial Objects
LTC Kelly Ward	U.S. Army Geospatial Center	Representing Drop Zones as Tactical Spatial Objects
Dr. Greg Parnell	Advanced Science & Technology Directorate, ARMDEC	Swarming of Lightweight Unmanned Aircraft Systems (UAS)
Dr. Greg Parnell	NSA	Information Security for Acquisition Programs
LTC Dan McCarthy/MAJ Julia Oh	Department of Veterans Affairs	VA Claims Process Improvement
LTC Dan McCarthy/LTC Kenny McDonald	USMA G-3	USMAPS Interim Facilities Planning
LTC Kenny McDonald	Mini Baja - CME	Mini Baja - CME
LTC Suzanne DeLong	STRATCOM	Prompt Global Strike Analysis or Strategic Deterrence



# Capstone Projects *2 of 3*



Capstone Advisor	Supported Agency	Project Title
Dr. Tim Elkins	US Army - RDECOM - ARDEC	Hybrid Projectile Systems Engineering Support
Dr. Tim Elkins	Army G1, Strength Analysis & Forecasting	Personnel Friction Systems Engineering Support
COL Donna Korycinski	U.S. Army MEDICAL Command	Reserve Component MEB/PEB Lean Six Sigma Process Improvement
COL Donna Korycinski	USMA SGS	USMA SGS Tasking System Lean Six Sigma Process Improvement
MAJ Steve Henderson	Defense Advanced Research Projects Agency (DARPA) Information Processing Techniques Office (IPTO)	Urban Leader Tactical Response, Awareness & Visualization (ULTRA-Vis)
MAJ Steve Henderson	PEO Soldier, Product Manager – Air Warrior	Overcoming Information Overload
MAJ John Hiltz	Product Manager – Individual Weapons (PEO Soldier)	Basis of Issue Modeling for the XM-25 Individual Airburst Weapon System
MAJ Mike Rainey	PEO Soldier – Team Soldier (Soldier Warrior)	Terrain Based Decision Aides for the Small Unit Leader - Support by Fire Positions (PEO Soldier)
MAJ Matt Dabkowski	Office of Strategic Planning and Transformation, US Military Entrance Processing Command	Developing an Ideal MEPS
MAJ Matt Dabkowski	AMRDEC	Swarming of Lightweight Unmanned Aircraft Systems (UAS) II



# Capstone Projects *3 of 3*



Capstone Advisor	Supported Agency	Project Title
COL Tim Trainor	Federal Aviation Administration	Design a Vertical-Axis Wind Turbine
COL Tim Trainor	OSD PAE	Fleet Management Approach to Generate Sustainment Resource Requirements
Dr. Roger Burk	Project Manager for Unmanned Aircraft Systems (PM UAS)	User Interface for Ground Based Sense and Avoid
Dr. Roger Burk	U.S. Army Space and Missile Defense Command/ Army Forces Strategic Command	ISR Analysis
Dr. Paul West	AFRL Sensors Directorate	Simulating malevolent Behavioral Intent on College Campuses
Dr. Paul West	West Point Security Office	Stadium Evacuation System
Dr. Pat Driscoll	Army G-1	Developing feasible officer manning policies & structure
Dr. Pat Driscoll	OSE(P&R) Readiness Directorate	Developing a new rotation rate metric for the services
LTC Rob Kewley	Lawrence Livermore National Laboratories	High Energy Laser Base Defense System